

A Regional and National Database Comparison of Colorectal Outcomes

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ABSTRACT

Background and Objectives: The traditional open approach is still a common option for colectomy and the most common option chosen for rectal resections for cancer. Randomized trials and large database studies have reported the merits of the minimally invasive approach, while studies comparing laparoscopic and robotic options have reported inconsistent results.

Methods: This study was designed to compare open, laparoscopic, and robotic colorectal surgery outcomes in protocol-driven regional and national databases. Logistic and multiple linear regression analyses were used to compare standard 30-day colorectal outcomes in the Michigan Surgical Quality Collaborative (MSQC) and American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) databases. The primary outcome was overall complications.

Results: A total of 10,054 MSQC patients (open 37.5%, laparoscopic 48.8%, and robotic 13.6%) and 80,535 ACS-NSQIP patients (open 25.0%, laparoscopic 67.1%, and robotic 7.9%) met inclusion criteria. Overall complications and surgical site infections were significantly favorable for the laparoscopic and robotic approaches compared with the open approach. Anastomotic leaks were significantly

fewer for the laparoscopic and robotic approaches compared with the open approach in ACS-NSQIP, while there was no significant difference between robotic and open approaches in MSQC. Laparoscopic complications were significantly less than robotic complications in MSQC but significantly more in ACS-NSQIP. Laparoscopic 30-day mortality was significantly less than for the robotic approach in MSQC, but there was no difference in ACS-NSQIP.

Conclusion: Minimally invasive colorectal surgery is associated with fewer complications and has several other outcomes advantages compared with the traditional open approach. Individual complication comparisons vary between databases, and caution should be exercised when interpreting results in context.

Key Words: Minimally invasive, Laparoscopic, Robotic, Colorectal surgery.

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INTRODUCTION

Multiple studies have shown favorable short-term minimally invasive (MIS) colorectal surgery outcomes compared with the open colectomy (OC) approach.¹⁻⁵ Even so, adoption of the laparoscopic colectomy (LC) method plateaued at 22-55% of colorectal procedures, resulting in the evolution, adoption, and critical analysis of the robotic colectomy (RC) platform.⁶⁻⁸

As MIS options continue to evolve beyond current LC limitations and RC learning curves, studies designed to compare surgical options help determine the current role for each approach. Although randomized trials are considered the optimal study design, they are limited in colorectal surgery to MIS surgeons who have unique expertise and whose results may not be generalizable.^{9,10} Large risk-adjusted databases offer power in comparison and are potentially generalizable due to large patient numbers contributed by surgeons with varying skill sets and expertise, but these databases are also limited by the reliability of data abstraction and interpretation and lack of certain details.

The purpose of this study was to compare the results of OC, LC, and RC colorectal surgery outcomes in a large

regional risk-adjusted and a large national risk-adjusted database.

METHODS

This study is a retrospective outcomes comparison of OC, LC, and RC colorectal surgery using data from the national American College of Surgeons-National Surgical Quality Program (ACS-NSQIP) database from January 1, 2012, through December 31, 2016, and from the regional 72-hospital Michigan Surgical Quality Collaborative (MSQC) database from July 1, 2012, through August 20, 2017. Both risk-adjusted databases employ certified and trained data abstractors who collect patient demographics and preoperative and 30-day postoperative information on surgical patients. This study was approved by the Institutional Review Board at Saint Joseph Mercy Health System, Ann Arbor, Michigan.

Inclusion Criteria

The following CPT codes were used to query cases: OC (44140, 44160), open pelvic operations (44145, 44146, 45110), MIS colectomy (44204, 44205), and MIS pelvic operations (44207, 44208, 45395). Both MSQC and NSQIP database dictionaries distinguish LC from RC cases. Exclusion criteria were pediatric patients (younger than 18 years), urgent and emergent operations, and patients with American Society of Anesthesiologists (ASA) classification of 5 (moribund) or 6 (brain death). The study was designed to compare MIS completed operations, so LC and RC converted cases were excluded.

Variables for Statistical Model

Preoperative variables for both databases included age, sex, body mass index (BMI), and race/ethnicity. Comorbidities included tobacco use, diabetes, ventilator dependence, hypertension, congestive heart failure, chronic obstructive pulmonary disease, ascites, disseminated cancer, weight loss (>10% in the past 6 months), presence of bleeding disorders, diagnosis (colorectal cancer, colorectal adenomas/polyps, diverticular disease, other), and ASA classification. Both databases also included a variable for operative time, which was considered as a covariate except for the model in which operative time 100 minutes was the outcome. The MSQC database additionally included history of sleep apnea, deep vein thrombosis (DVT), coronary artery disease (CAD), peripheral vascular disease, steroid use, history of alcohol abuse, hospital volume, and surgeon volume. The ACS-NSQIP database

also included location of surgery (right colectomy, sigmoid colectomy, total colectomy, or rectal resection).

Outcomes

The primary outcome in this study was overall 30-day complications. Secondary outcomes of interest were hospital length of stay (LOS), operative time, surgical site infections (SSIs), urinary tract infections (UTIs), DVT, cardiac complications, pneumonia, unplanned intubation, renal failure, anastomotic leaks, 30-day readmission, 30-day reoperation, discharge destination not home, and 30-day mortality. Operative time was defined as the duration of operation from skin incision to skin closure. Anastomotic leak was defined as extravasation of contrast medium at computed tomography scan or contrast enema.

Statistical Analysis

Patients in the OC, LC, and RC groups were compared by demographics and presurgical health histories with the use of χ^2 tests for categorical variables and *t*-tests for interval variables. Given the significant differences in patient backgrounds, logistic (categorical outcomes) and linear (continuous outcome) regression analyses were performed that adjusted for the pretreatment variables. The results of the logistic regressions are summarized by using odds ratios (ORs) and the corresponding 95% confidence intervals (CIs). Significant differences in outcomes between surgery types are identified when the 95% CIs do not include 1. The results of the linear regression analyses are summarized with the estimated slope and the corresponding 95% CI. Significant differences are identified when the 95% CI around the estimated slope does not include 0.

RESULTS

A total of 10,054 MSQC patients (3775 [37.6%] OC, 4908 [48.8%] LC, and 1371 [13.6%] RC) and 80,535 ACS-NSQIP patients (20,116 [25.0%] OC, 54,077 [67.1%] LC, and 6342 [7.9%] RC) met inclusion criteria. Patient characteristics for both MSQC and ACS-NSQIP groups are depicted in **Table 1** and are summarized in the following. There were significant differences in all measured MSQC and ACS-NSQIP patient characteristics except alcohol use and ventilator dependence in the MSQC population. MSQC/ACS-NSQIP BMI ≥ 30 kg/m² accounted for 38.1%/33.9% of OC, 38.2%/35.0% of LC, and 39.5%/37.6% of RC cases, respectively. The OC group in both MSQC and ACS-NSQIP had significantly more patients of ASA 3/4 categories. Colorectal neoplasia and diverticular disease constituted 54.5% and

Table 1.
Patient Characteristics

Covariate	MSQC (n = 10,054)			NSQIP (n = 80,535)		
	Open (n = 3,775)	Lap (n = 4,908)	Robot (n = 1,371)	Open (n = 20,116)	Lap (n = 54,077)	Robot (n = 6,342)
Age, mean (SD)	64 (13.8)	62 (13.4)	61 (12.9)	62 (14.7)	60 (14.5)	60 (12.9)
BMI, n (%)						
<18.5 or Unknown	117 (3.1)	113 (2.3)	15 (1.1)	731 (3.6)	1226 (2.3)	85 (1.3)
18.5–24.9	983 (26.0)	1206 (24.6)	346 (25.2)	6094 (30.3)	15170 (28.1)	1664 (26.2)
25–29.9	1236 (32.7)	1717 (35.0)	469 (34.2)	6470 (32.2)	18783 (34.7)	2204 (34.8)
30–34.9	796 (21.1)	1103 (22.5)	290 (21.2)	3820 (19)	11400 (21.1)	1430 (22.5)
>= 35	643 (17.0)	769 (15.7)	251 (18.3)	3001 (14.9)	7498 (13.9)	959 (15.1)
Male Gender, n (%)	1679 (44.5)	2321 (47.3)	681 (49.7)	9413 (46.8)	25866 (47.8)	3179 (50.1)
Race, n (%)						
Caucasian	3224 (85.4)	4158 (84.7)	1185 (86.4)	15404 (76.6)	42061 (77.8)	5276 (83.2)
African American	431 (11.4)	506 (10.3)	125 (9.1)	1777 (8.8)	4455 (8.2)	497 (7.8)
Asian				459 (2.3)	1666 (3.1)	206 (3.2)
Other	120 (3.2)	244 (5.0)	61 (4.4)	2476 (12.3)	5895 (10.9)	363 (5.7)
Partially/Totally Dependent, n (%)	126 (3.3)	83 (1.7)	9 (0.7)	388 (1.9)	530 (1)	43 (0.7)
Tobacco Use, n (%)	849 (22.5)	962 (19.6)	300 (21.9)	3561 (17.7)	8312 (15.4)	956 (15.1)
Alcohol Use, n (%)	129 (3.4)	151 (3.1)	42 (3.1)			
Steroids, n (%)	233 (6.2)	199 (4.1)	52 (3.8)			
Diabetes, n (%)	798 (21.1)	887 (18.1)	256 (18.7)	3118 (15.5)	7435 (13.7)	955 (15.1)
Ventilator Dependent, n (%)	2 (0.1)	3 (0.1)	0 (0.0)	11 (0.1)	4 (0)	0 (0)
Hypertension, n (%)	2173 (57.6)	2578 (52.5)	715 (52.2)	9685 (48.1)	24788 (45.8)	2946 (46.5)
Coronary Artery Disease	657 (17.4)	635 (12.9)	183 (13.3)			
CHF, n (%)	32 (0.8)	13 (0.3)	5 (0.4)	170 (0.8)	257 (0.5)	19 (0.3)
COPD	411 (10.9)	364 (7.4)	114 (8.3)	1019 (5.1)	2094 (3.9)	210 (3.3)
Sleep Apnea	542 (14.4)	817 (16.6)	248 (18.1)			
Peripheral Vascular Disease, n (%)	129 (3.4)	91 (1.9)	21 (1.5)			
DVT	272 (7.2)	224 (4.6)	53 (3.9)			
Ascites, n (%)	29 (0.8)	6 (0.1)	0 (0.0)	155 (0.8)	62 (0.1)	3 (0)

Table 1.
Continued

Covariate	MSQC (n = 10,054)			NSQIP (n = 80,535)			p-value†
	Open (n = 3,775)	Lap (n = 4,908)	Robot (n = 1,371)	Open (n = 20,116)	Lap (n = 54,077)	Robot (n = 6,342)	
Disseminated Cancer, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	2290 (11.4)	1611 (3)	218 (3.4)	<0.0001*
Weight Loss > 10%, n (%)	169 (4.5)	100 (2.0)	39 (2.8)	1073 (5.3)	1439 (2.7)	121 (1.9)	<0.0001*
Bleeding Disorder, n (%)	139 (3.7)	95 (1.9)	19 (1.4)	588 (2.9)	1016 (1.9)	118 (1.9)	<0.0001*
Diagnosis, n (%)							<0.0001*
Colorectal Cancer	1706 (45.2)	1858 (37.9)	597 (43.5)	8853 (44)	22112 (40.9)	3101 (48.9)	
Colorectal Adenomas/ Polyps	348 (9.2)	806 (16.4)	163 (11.9)	1190 (5.9)	8147 (15.1)	724 (11.4)	
Diverticular Disease/ Fistulas	751 (19.9)	1329 (27.1)	341 (24.9)	2887 (14.4)	13121 (24.3)	1772 (27.9)	
Other	970 (25.7)	915 (18.6)	270 (19.7)	7186 (35.7)	10697 (19.8)	745 (11.7)	
ASA Classification, n (%)							<0.0001*
ASA 1 or 2	1426 (37.8)	2537 (51.7)	732 (53.4)	8108 (40.3)	30152 (55.8)	3340 (52.7)	
ASA 3	2140 (56.7)	2226 (45.4)	613 (44.7)	11058 (55)	22540 (41.7)	2895 (45.6)	
ASA 4	209 (5.5)	145 (3.0)	26 (1.9)	950 (4.7)	1385 (2.6)	107 (1.7)	
Operative Segment n (%)							<0.0001*
Abdominal, Right				5265 (26.2)	12857 (23.8)	1122 (17.7)	
Abdominal, Sigmoid				7108 (35.3)	22790 (42.1)	2023 (31.9)	
Abdominal, Total				1058 (5.3)	2422 (4.5)	128 (2)	
Rectum				6685 (33.2)	16008 (29.6)	3069 (48.4)	
Surgery Time, mean (SD)	199 (100.4)	224 (106.7)	260 (101.3)	187 (112.8)	176 (83.5)	228 (96.5)	<0.0001*
Hospital Volume, mean (SD)	199 (100.4)	224 (106.7)	260 (101.3)				<0.0001*
Surgeon Volume, mean (SD)	42 (43.7)	56 (46.4)	68 (45.1)				<0.0001*

BMI = Body Mass Index, ASA = American Society of Anesthesiology.

† p values based on Chi-Square test or Kruskal-Wallis test.

*Significant difference, p < 0.05.

Table 2. Unadjusted Postoperative Outcomes by Surgical Approach

Postoperative Outcome	MSQC				NSQIP			
	Unadjusted Values		Unadjusted P-Value†		Unadjusted Values		Unadjusted P-Value†	
	Open	Lap	Robot	Open vs Lap vs Robot	Open	Lap	Robot	Open vs Lap vs Robot
Hospital Length of Stay, mean days	7.1	4.5	4.2	<0.0001* <0.0001* 0.0232*	8	5	4	<0.0001* <0.0001* <0.0001*
Operative Duration >100 min, n (%)	2545 (67.4)	3686 (75.1)	1241 (90.5)	<0.0001* <0.0001* <0.0001*	16034 (79.7)	45843 (84.8)	6034 (95.1)	<0.0001* <0.0001* <0.0001*
Any Complication, n (%)	917 (24.3)	599 (12.2)	209 (15.4)	<0.0001* <0.0001* 0.0089*	7931 (39.5)	11013 (20.4)	1229 (19.4)	<0.0001* <0.0001* 0.19
SSI, n (%)	377 (10.0)	197 (4.0)	73 (5.3)	<0.0001* <0.0001* 0.1032	1731 (8.6)	1957 (3.6)	178 (2.8)	<0.0001* <0.0001* 0.0031*
UTI, n (%)	115 (3.1)	57 (1.2)	20 (1.5)	<0.0001* 0.0049*	1.0000	864 (1.6)	91 (1.4)	<0.0001* <0.0001* >0.9999
DVT, n (%)	42 (1.1)	25 (0.5)	7 (0.5)	0.0044* 0.1479	1.0000	274 (1.4)	36 (0.6)	<0.0001* 0.0001* 0.504
Any Cardiac Complication, n (%)	19 (0.5)	12 (0.2)	8 (0.6)	0.1351 1.0000	0.1467	230 (1.1)	35 (0.6)	<0.0001* 0.0002* >0.9999
Pneumonia, n (%)	91 (2.4)	32 (0.7)	13 (1.0)	<0.0001* 0.0029*	0.7510	447 (2.2)	52 (0.8)	<0.0001* <0.0001* 0.867
Unplanned Intubation, n (%)	77 (2.0)	49 (1.0)	17 (1.2)	0.0002* 0.1747	1.0000	342 (1.7)	41 (0.6)	<0.0001* <0.0001* >0.9999
Renal Failure or Insufficiency, n (%)	124 (3.3)	79 (1.6)	39 (2.8)	<0.0001* 1.0000	0.0087*	303 (1.5)	59 (0.9)	<0.0001* 0.0022* 0.0019*
Anastomotic Leak††, n (%)	94 (2.7)	79 (1.6)	35 (2.7)	0.0033* 1.0000	0.0299*	818 (4.3)	178 (2.9)	<0.0001* <0.0001* 0.423
Readmission within 30 Days, n (%)	472 (12.5)	381 (7.8)	135 (9.9)	<0.0001* 0.0270*	0.0390*	2515 (12.5)	533 (8.4)	<0.0001* <0.0001* 0.153
Reoperation within 30 Days, n (%)	304 (8.1)	266 (5.4)	103 (7.5)	<0.0001* 1.0000	0.0107*	1037 (5.2)	271 (4.3)	<0.0001* 0.0157* 0.0018
Not Discharged Home, n (%)	1251 (33.1)	658 (13.4)	352 (25.7)	<0.0001* <0.0001*	<0.0001*	1037 (5.2)	271 (4.3)	<0.0001* <0.0001* 0.137
Death within 30 Day, n (%)	55 (1.5)	21 (0.4)	12 (0.9)	<0.0001* 0.3110	0.1284	222 (1.1)	19 (0.3)	<0.0001* <0.0001* 0.666

†p-values based on Chi-Square test or Least Squares Means test and includes Bonferroni correction for multiple comparisons.

*Significant difference, p < 0.05.

Table 3.
Risk Adjusted Postoperative Outcomes by Surgical Approach

Postoperative Outcome	MSQC (n = 10,054)		ACS-NSQIP (n = 80,535)		MSQC (n = 10,054)		ACS-NSQIP (n = 80,535)		MSQC (n = 10,054)		ACS-NSQIP (n = 80,535)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Open vs Lap												
Open vs Robot												
Lap vs Robot												
<i>Continuous</i>												
Hospital Length of Stay	2.6150	2.4476 2.7823	2.219	2.131 2.307	2.9359	2.6922 3.1796	2.977	2.826 3.128	0.3209	0.0848 0.5570	0.759	0.622 0.896
<i>Binary</i>												
Operative Duration >100 min	0.5294	0.4816 0.5820	0.613	0.586 0.641	0.1893	0.1560 0.2297	0.2	0.177 0.226	0.3576	0.2946 0.4340	0.3226	0.29 0.368
Any Complication	1.6149	1.4424 1.8081	2.098	2.021 2.178	1.3370	1.1352 1.5747	2.502	2.327 2.69	0.8279	0.7022 0.9761	1.192	1.113 1.277
SSI	2.1091	1.7689 2.5148	2.328	2.169 2.498	1.7604	1.3548 2.2874	3.222	2.744 3.784	0.8347	0.6353 1.0966	1.384	1.183 1.619
UTI	1.9429	1.4159 2.6662	1.636	1.466 1.825	1.6831	1.0466 2.7067	2.028	1.615 2.546	0.8663	0.5284 1.4202	1.24	0.994 1.547
DVT	1.5932	0.9730 2.6087	1.527	1.295 1.8	1.7883	0.8009 3.9933	2.034	1.424 2.906	1.1225	0.4954 2.5436	1.334	0.943 1.887
Any Cardiac Complication	1.2999	0.6264 1.2531	1.59	1.325 1.908	0.4878	0.2208 1.0774	1.598	1.106 2.311	0.3752	0.1699 0.8286	1.005	0.702 1.439
Pneumonia	2.6007	1.7502 3.8646	1.714	1.497 1.963	1.7974	1.0286 3.1409	1.908	1.416 2.57	0.6911	0.3786 1.2616	1.113	0.831 1.49
Unplanned Intubation	1.3585	0.9466 1.9538	1.721	1.474 2.009	1.0033	0.6122 1.6441	1.962	1.403 2.743	0.7385	0.4496 1.2131	1.141	0.821 1.586
Renal Failure or Insufficiency	1.5324	1.1542 2.0347	2.038	1.722 2.412	0.9870	0.6801 1.4323	1.501	1.123 2.006	0.8279	0.4404 0.9419	0.736	0.553 0.98
Anastomotic Leak	1.4851	1.0978 2.0092	1.496	1.362 1.644	0.9500	0.6367 1.4175	1.498	1.263 1.776	0.8279	0.4272 0.9580	1.002	0.852 1.179
Readmission within 30 Days	1.3364	1.1592 1.5407	1.436	1.36 1.517	1.1564	0.9422 1.4194	1.42	1.283 1.573	0.8653	0.7055 1.0613	0.989	0.898 1.089
Reoperation within 30 Days	1.2073	1.0177 1.4322	1.3	1.197 1.411	0.9533	0.7527 1.2072	1.105	0.96 1.273	0.7896	0.6254 0.9968	0.85	0.744 0.972
Not Discharged Home	2.1450	1.9323 2.3811	2.038	1.892 2.196	1.2790	1.1086 1.4756	2.487	2.118 2.92	0.5963	0.5152 0.6901	1.22	1.041 1.43
Death within 30 Day	2.1680	1.3198 3.5625	1.713	1.402 2.092	0.9092	0.5134 1.6101	2.028	1.252 3.284	0.4193	0.2251 0.7810	1.184	0.734 1.91

Note: Estimates for continuous outcomes are mean differences from multiple regression. Estimates for binary outcomes are odds ratios from logistic regressions. CI = Confidence Intervals. Bold indicates significance.

24.1% of the MSQC and 53.9% and 22.3% of the ACS-NSQIP patient populations, respectively. Rectal resections constituted a significantly larger proportion of cases in the RC group compared with the OC and LC groups (OC 33.2%, LC 29.6%, RC 48.4%).

Table 2 displays unadjusted MSQC and ACS-NSQIP outcomes that are summarized by the following. The number of operative cases with duration >100 minutes is significantly higher and the hospital LOS is significantly shorter for the patients who received the RC approach.

OC vs LC

Overall complications and all other OC-vs-LC outcomes are significantly different in favor of the LC approach except for cardiac complications in the MSQC database, where there is no significant difference.

OC vs RC

Overall complications and all other OC-vs-RC ACS-NSQIP outcomes are significantly different in favor of the RC approach. Significantly different outcomes in the ACS-NSQIP database that are not significantly different in MSQC are given for DVT, cardiac complications, unplanned reintubation, renal failure, anastomotic leak, 30-day reoperation, and 30-day mortality.

LC vs RC

The overall complication rate is significantly less for the LC group than for the RC group in the MSQC database, while there is no significant difference in the ACS-NSQIP database analysis. SSIs are significantly fewer for the RC approach in ACS-NSQIP but not in MSQC. Anastomotic leaks and 30-day readmissions are significantly less with the LC approach compared with the RC approach in MSQC, but there is no significant difference in ACS-NSQIP. There are significantly fewer 30-day reoperations for the LC group compared with the RC group in both databases.

Table 3 and **Figure 1** show ORs for MSQC and ACS-NSQIP adjusted outcomes for the colorectal study group.

Table 4 and **Figure 2** show subgroup analyses of ORs for MSQC and ACS-NSQIP risk-adjusted outcomes for colectomies, and **Table 5** and **Figure 3** provide the same for rectal resections. These tables and figures are summarized as follows.

Overall Complication Rate

The overall complication rate was significantly higher in the OC group compared with the LC and RC groups, and this finding remained significant in colectomy and rectal

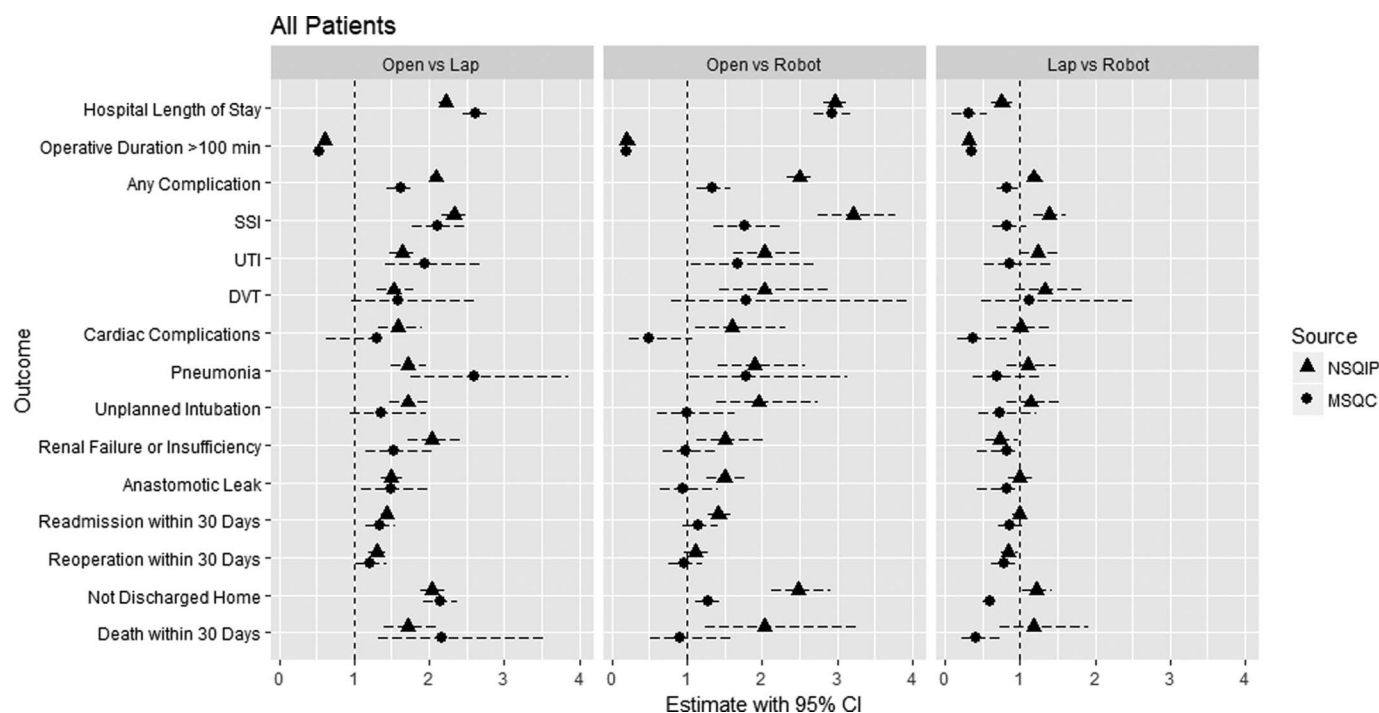


Figure 1. Outcomes for all patients: OC vs LC, OC vs RC, and LC vs RC.

Table 4. Risk Adjusted Postoperative Outcomes by Surgical Approach for Colectomy Patients

Postoperative Outcome	MSQC (n = 7,044)		ACS-NSQP (n = 54,773)		MSQC (n = 7,044)		ACS-NSQP (n = 54,773)		MSQC (n = 7,044)		ACS-NSQP (n = 54,773)	
	Open vs Lap	Estimate 95% CI	Estimate 95% CI	Estimate 95% CI	Open vs Robot	Estimate 95% CI	Estimate 95% CI	Estimate 95% CI	Lap vs Robot	Estimate 95% CI	Estimate 95% CI	Estimate 95% CI
<i>Continuous</i>												
Hospital Length of Stay	2.3885	2.1947 2.5823	2.249	2.141 2.357	2.9184	2.6194 3.2173	3.208	3.002 3.414	0.5299	0.2425 0.8172	0.959	0.769 1.149
<i>Binary</i>												
Operative Duration >100 min	0.4915	0.4412 0.5477	0.606	0.576 0.638	0.2345	0.1903 0.2889	0.176	0.151 0.204	0.4770	0.3878 0.5866	0.29	0.25 0.336
Any Complication	1.4790	1.2901 1.6956	2.119	2.026 2.217	1.2460	1.0100 1.5372	2.68	2.426 2.962	0.8425	0.6844 1.0370	1.265	1.149 1.392
SSI	1.9368	1.5570 2.4092	2.264	2.077 2.468	1.6949	1.1929 2.4081	3.031	2.443 3.761	0.8751	0.6114 1.2525	1.339	1.084 1.655
UTI	1.9962	1.3262 3.0049	1.621	1.408 1.867	2.1732	1.0510 4.4935	1.839	1.338 2.526	1.0886	0.5176 2.2899	1.134	0.832 1.546
DVT	2.0557	1.1246 3.7576	1.568	1.297 1.897	2.5357	0.8123 7.9152	2.354	1.442 3.842	1.2335	0.3847 3.9555	1.501	0.928 2.426
Cardiac Complications	1.1527	0.5052 2.6304	1.578	1.269 1.961	0.3670	0.1496 0.9000	1.829	1.08 3.099	0.3183	0.1356 0.7475	1.16	0.692 1.942
Pneumonia	2.4201	1.5320 3.8231	1.684	1.439 1.97	1.4062	0.7397 2.6733	2.366	1.558 3.591	0.5811	0.2942 1.1478	1.406	0.934 2.118
Unplanned Intubation	1.3216	0.8708 2.0058	1.829	1.531 2.187	0.7722	0.4439 1.3433	2.098	1.366 3.223	0.5843	0.3384 1.0088	1.147	0.751 1.751
Renal Failure/Insufficiency	1.6180	1.1378 2.3010	2.081	1.674 2.587	1.1077	0.6678 1.8376	1.784	1.11 2.867	0.6846	0.4103 1.1423	0.858	0.538 1.368
Anastomotic Leak	1.2443	0.8654 1.7892	1.669	1.481 1.881	0.8811	0.5282 1.4699	2.217	1.678 2.928	0.7081	0.4288 1.1694	1.328	1.016 1.738
Readmission within 30 Days	1.2964	1.0877 1.5451	1.451	1.354 1.554	1.2442	0.9434 1.6408	1.567	1.355 1.811	0.9597	0.7309 1.2603	1.08	0.94 1.241
Reoperation within 30 Days	1.1454	0.9249 1.4186	1.401	1.267 1.548	0.9858	0.7158 1.3577	1.257	1.03 1.536	0.8607	0.6305 1.1749	0.898	0.744 1.083
Not Discharged Home	2.0019	1.7525 2.2868	2.038	1.866 2.226	1.2137	1.0008 1.4720	2.452	1.984 3.03	0.6063	0.4990 0.7367	1.203	0.976 1.484
Death within 30 Day	2.7455	1.5286 4.9314	1.811	1.449 2.265	0.7284	0.3916 1.3550	1.744	0.997 3.048	0.2653	0.1318 0.5341	0.963	0.554 1.673

Note: Estimates for continuous outcomes are mean differences from multiple regression. Estimates for binary outcomes are odds ratios from logistic regressions.

CI = Confidence Interval.

Bold indicates significance.

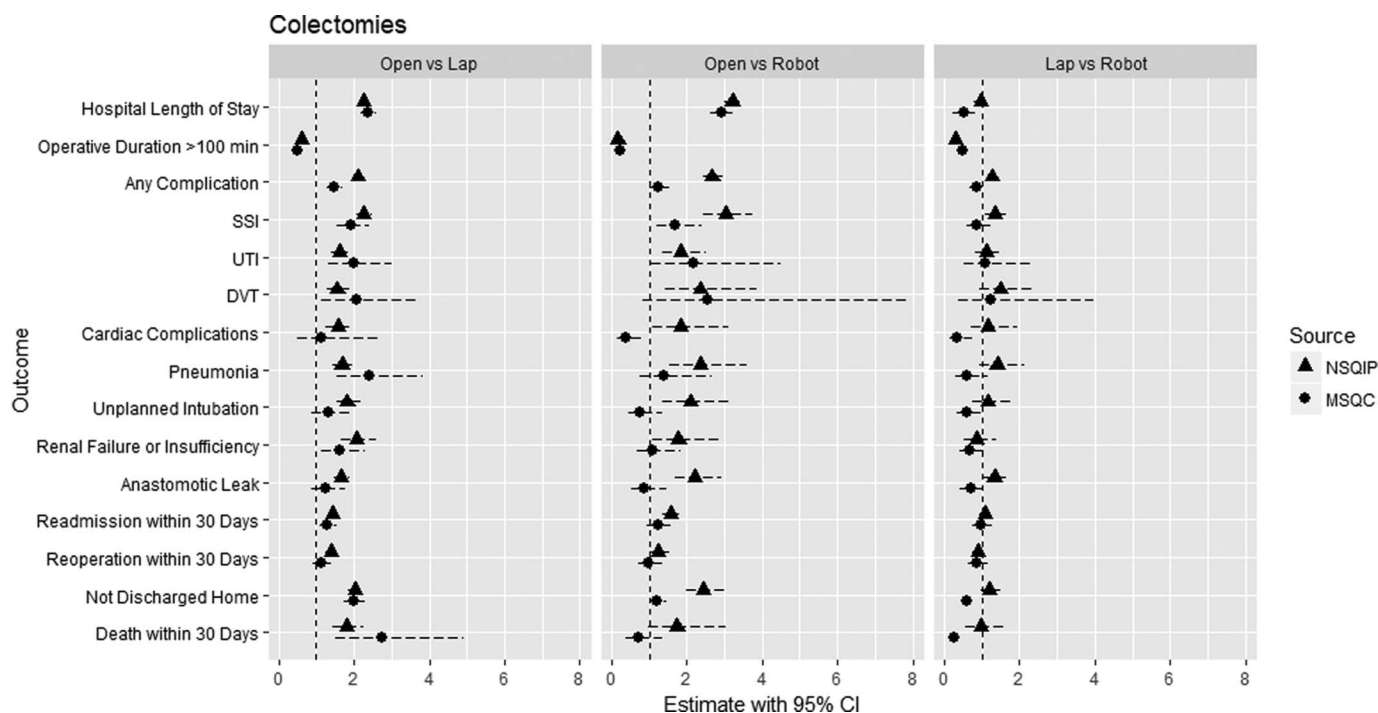


Figure 2. Colectomy outcomes for OC vs LC, OC vs RC, and LC vs RC.

resection subgroup analyses. When comparing the LC and RC groups, MSQC and ACS-NSQIP results differed. In the MSQC analysis, there were significantly fewer complications in the LC group and the LC rectal resection subgroup with no significant difference in the colectomy subgroup. In contrast, there were significantly more complications in the LC group compared with the RC group in the ACS-NSQIP analysis, and this finding was also significantly different in both colectomy and rectal resection subgroup analyses.

Operative Times and Hospital LOS

Cases with operative times >100 minutes were significantly longer in the RC group than in the LC and OC groups in both MSQC and ACS-NSQIP databases, and this finding remained significant in colectomy and rectal resection subgroups analyses. Hospital LOS was significantly shorter for the RC group than for the LC and OC groups in both MSQC and ACS-NSQIP databases, and this finding remained significant in the colectomy subgroup analysis. In the rectal resection subgroup, hospital LOS was not significantly different in MSQC.

Individual Complications

SSIs were significantly more common in all OC groups compared with the LC and RC groups in both MSQC and

ACS-NSQIP databases. When comparing the LC and RC approaches, SSIs were significantly fewer in the RC group and RC subgroups in ACS-NSQIP, while there was no significant difference between LC and RC groups and subgroups in MSQC.

Anastomotic leaks were significantly more common in all OC groups compared with the LC and RC groups and subgroups in the ACS-NSQIP database. In the MSQC database, anastomotic leaks were significantly more frequent in the OC group than in the LC group except in colectomy subgroups analyses, where there was no significant difference. There was no significant difference in anastomotic leaks in MSQC when comparing the OC and RC groups and subgroups. When comparing the LC and RC groups, MSQC and ACS-NSQIP analyses revealed contrasting results. Anastomotic leaks were significantly fewer in the MSQC LC group and the LC rectal resection subgroup compared with the RC group, and there was no significant difference between the LC and RC colectomy subgroups. In the ACS-NSQIP database, there was no significant difference in anastomotic leaks between the LC and RC groups except in colectomy subgroup analysis, where there were significantly fewer anastomotic leaks in the RC group.

The 30-day mortality was significantly more frequent in the OC group than in the LC group and colectomy sub-

Table 5.
Risk Adjusted Postoperative Outcomes by Surgical Approach for Rectal Resection Patients

Postoperative Outcome	MSQC (n = 3,010)		ACS-NSQIP (n = 25,762)		MSQC (n = 3,010)		ACS-NSQIP (n = 25,762)		MSQC (n = 3,010)		ACS-NSQIP (n = 25,762)		
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	
<i>Continuous</i>													
Total Hospital Length of Stay	3.0210	2.6931 3.3488	2.146	1.993 2.299	2.708	2.483 2.933	3.1054	2.6822 3.5287	0.0844	-0.3383	0.5072	0.562	0.362 0.762
<i>Binary</i>													
Operative Duration >100 min	0.5772	0.4662 0.7148	0.58	0.524 0.643	0.265	0.215 0.327	0.1307	0.0799 0.2138	0.2264	0.1372	0.3733	0.456	0.373 0.558
Any Complication	1.9748	1.6051 2.4296	2.052	1.92 2.194	2.321	2.088 2.58	1.4376	1.1123 1.8582	0.7280	0.5539	0.9568	1.131	1.023 1.25
SSI	2.3682	1.7414 3.2206	2.469	2.174 2.805	3.442	2.705 4.38	1.7120	1.1735 2.4977	0.7229	0.4757	1.0987	1.392	1.098 1.765
UTI	1.7909	1.0786 2.9735	1.619	1.355 1.935	2.266	1.637 3.137	1.3023	0.7059 2.4026	0.7272	0.3737	1.4152	1.399	1.021 1.919
DVT	1.2752	0.5390 3.0172	1.435	1.024 2.01	1.626	0.948 2.787	1.4150	0.4335 4.6184	1.1096	0.3281	3.7525	1.133	0.678 1.894
Cardiac Complications	2.9514	0.4351 20.0195	1.644	1.171 2.307	1.35	0.794 2.296	1.0986	0.1776 6.7956	0.3722	0.0388	3.5715	0.821	0.491 1.372
Pneumonia	4.2601	1.7692 10.2581	1.822	1.379 2.407	1.507	0.971 2.337	2.8236	0.9807 8.1297	0.6628	0.1880	2.3363	0.827	0.536 1.275
Unplanned Intubation	1.7223	0.7925 3.7432	1.422	1.033 1.957	1.725	0.998 2.98	1.9138	0.6383 5.7387	1.1112	0.3462	3.5669	1.213	0.714 2.059
Renal Failure/Insufficiency	1.6256	1.0009 2.6403	1.998	1.53 2.608	1.405	0.962 2.051	0.9793	0.5664 1.6934	0.6024	0.3329	1.0904	0.703	0.485 1.021
Anastomotic Leak	2.2235	1.2484 3.9602	1.244	1.065 1.452	1.078	0.86 1.35	0.9997	0.5383 1.8564	0.4496	0.2250	0.8986	0.866	0.702 1.068
Readmission within 30 Days	1.4788	1.1548 1.8936	1.413	1.281 1.559	1.305	1.129 1.508	1.1670	0.8586 1.5860	0.7891	0.5725	1.0877	0.923	0.806 1.057
Reoperation within 30 Days	1.2630	0.9448 1.6884	1.102	0.951 1.276	0.919	0.745 1.133	0.9066	0.6412 1.2819	0.7178	0.5020	1.0264	0.834	0.69 1.009
Not Discharged Home	2.2533	1.8927 2.6825	2.028	1.768 2.326	2.537	1.982 3.248	1.4555	1.1735 1.8052	0.6459	0.5155	0.8094	1.251	0.979 1.598
Death within 30 Day	0.7866	0.2982 2.0752	1.39	0.898 2.151	2.71	1.041 7.053	1.1741	0.2892 4.7659	1.4926	0.3833	5.8123	1.948	0.76 4.992

Note: Estimates for continuous outcomes are mean differences from multiple regression. Estimates for binary outcomes are odds ratios from logistic regressions.

CI = Confidence Intervals.

Bold indicates significance.

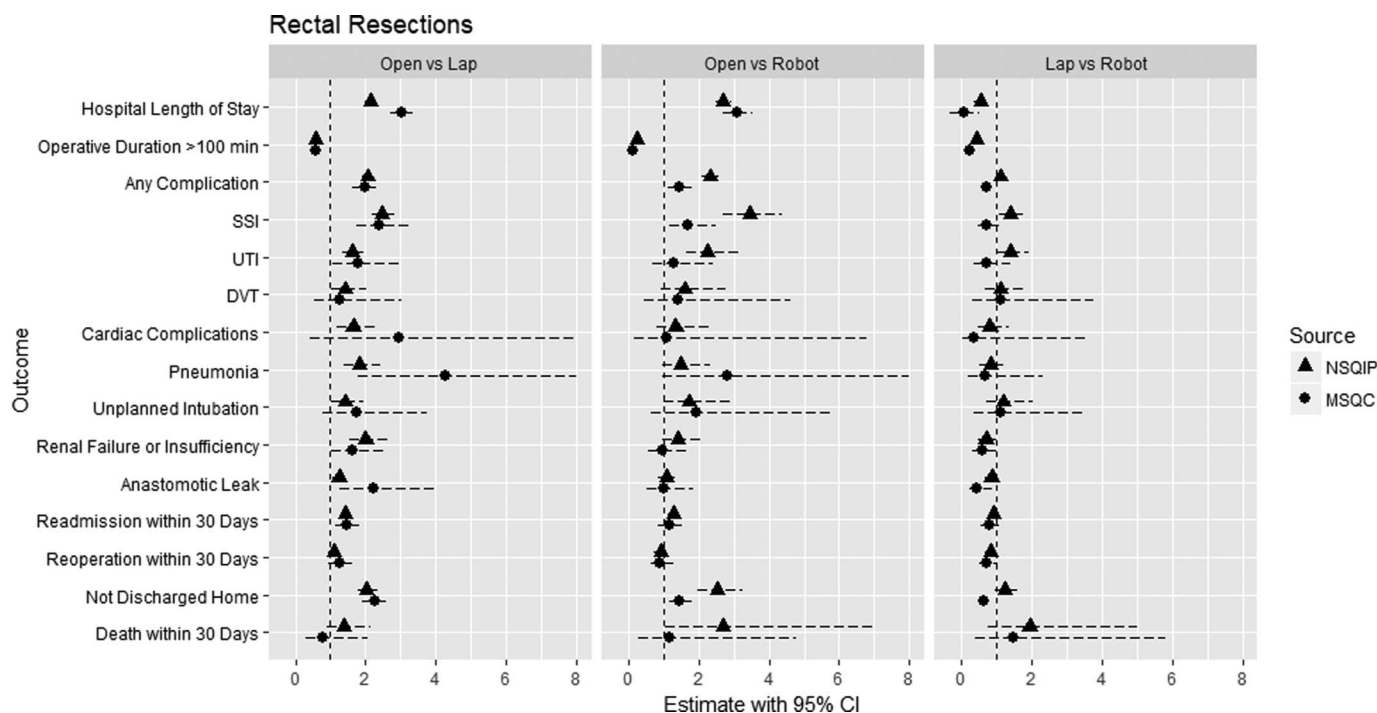


Figure 3. Rectal resection outcomes for OC vs LC, OC vs RC, and LC vs RC.

groups in both MSQC and ACS-NSQIP databases except in the MSQC rectal resection subgroup analysis, where there was no significant difference. There was no significant difference in 30-day mortality between the OC and RC groups and subgroups in MSQC, while 30-day mortality was significantly higher in the OC group compared with the RC groups and subgroups in ACS-NSQIP. When comparing LC and RC approaches, 30-day mortality was significantly less frequent in the LC group and colectomy subgroup. There was no significant difference in the rectal resection subgroup. There was no significant difference in ACS-NSQIP 30-day mortality between the LC and RC groups and subgroups.

The tables and figures reveal several other significant outcomes advantages for the LC and RC approaches compared with the OC group in both MSQC and ACS-NSQIP. In addition, the LC group had significantly fewer 30-day reoperations than the RC group in MSQC and significantly less renal failure complications in both databases.

DISCUSSION

This regional MSCQ and national ACS-NSQIP protocol-driven database analysis comparing traditional OC, LC, and RC colorectal surgery demonstrates several outcomes advantages for the MIS approach. The overall complica-

tion rate is significantly higher and hospital LOS is significantly longer for the OC approach. SSIs, anastomotic leaks, and several other individual complications are less frequent with MIS than with OC colorectal surgery. LC is associated with particularly favorable outcomes in the regional MSQC database with significantly fewer anastomotic leaks and less 30-day mortality than RC, findings that are not confirmed in the national ACS-NSQIP database, where there is no significant difference. Another contrasting finding in the comparison of the LC and RC groups is the frequency of SSIs—there is no significant difference in MSQC but SSIs are significantly more frequent in the LC group in ACS-NSQIP.

Determining the role of MIS in colorectal surgery presents several challenges. Although LC colectomy has been clearly demonstrated to have outcomes advantages and to be cost effective compared with the traditional OC approach, it is still considerably underused, with traditional OC surgery still common for colectomies and the most common approach for rectal resections.^{3,7,11} Randomized trials evaluating MIS approaches are conducted by MIS experts and may not be generalizable.^{9,10} MIS options are evolving and newer advances may require new studies. Large database analyses add power to comparisons because of patient numbers but have other limitations that

are difficult to define, suggesting that care be exercised in interpretation.^{12,13}

Other Studies Comparing MIS and OC Colorectal Approaches

Previous studies have confirmed the significantly decreased complication rates and shorter hospital LOS for the MIS approach compared with the OC approach.^{3,7} A study matching 67 OC with 67 LC institutional colorectal cases and 45 OC with 45 RC cases in the ACS-NSQIP database found a significantly lower overall complication rate (OC 49.2% vs. LC 22.4%, $P < .01$; OC 33.3% vs RC 6.7%, $P < .01$) and hospital LOS (OC 7 vs LC 5 days, $P < .01$; OC 7 vs. RC 5 days, $P < .01$) for the MIS approach compared with the OC approach.³ The study was an analysis of the authors' institutional data identified in the ACS-NSQIP database, while our study was a multi-institutional comparison of MSQC and ACS-NSQIP databases. There was an SSI outcome advantage for the LC group but not for the RC group in their study compared with the OC approach.³ Other studies have shown shorter hospital LOS and fewer SSIs for the RC approach compared with the OC approach.¹⁴

Colorectal operations were significantly longer for the RC group than for the LC and OC groups in both MSQC and ACS-NSQIP analyses, which is consistent with other studies.^{1,2,14,15} Although operating times decrease with experience, RC takes time to set up, and the operative dissection is characterized by shorter, slower, articulated movements using 3 arms. The longer RC operation times in these studies were not likely due to more complicated cases and did not appear to be accompanied by worse outcomes.

Other Studies Comparing Specific MIS and OC Colorectal Outcomes

Our study revealed significantly fewer anastomotic leaks for the LC group compared with the OC group in both MSQC and ACS-NSQIP databases and significantly fewer anastomotic leaks for the RC group compared with the OC group in the ACS-NSQIP database, with no significant difference in MSQC. Other studies comparing OC and MIS approaches for anastomotic leaks show inconsistent results, with one study suggesting there are fewer leaks with both RC and LC approaches compared with the OC approach.¹⁶

When comparing LC and RC in our study, there were significantly fewer anastomotic leaks for LC in MSQC and more for LC in the ACS-NSQIP colectomy subgroup analysis. Most other studies comparing RC and LC show no

difference in leak rates, which vary between 2.7% and 3.9%.^{1-4,8,15} Anastomotic leak is a major complication of colorectal surgery with high morbidity. Reoperation for anastomotic leaks accounts for 30–40% of deaths after resection for colorectal cancer.¹⁷ In our study, unadjusted leak rates for OC, LC, and RC were 2.7%, 1.6%, and 2.7%, respectively, in MSQC and 4.3%, 2.6%, and 2.9%, respectively, in ACS-NSQIP. The anastomotic leak rates in both databases in all groups in this study compare favorably with the rates from other studies, especially in the rectal resection subgroup analysis. It may be that the sample size in our study is so large that the statistically significant difference in these rates is not clinically different for this complication.^{3,4,8,16} Anastomotic leak rates are associated with several risk factors that are difficult to control for in statistical models. The reasons for inconsistent results in studies to date are not apparent at this time, and definitive conclusions based on these results would be difficult to determine.

Thirty-day mortality was another inconsistent finding between MSQC and ACS-NSQIP databases in our study. LC and RC groups have significantly fewer deaths than the OC group in the ACS-NSQIP database, while there was no significant difference between RC and OC approaches in MSQC. The LC group had significantly fewer deaths than the RC group in MSQC, but there was no significant difference in ACS-NSQIP. Adjusted death rates for OC, LC, and RC options were 1.1%, 0.5%, and 1.2%, respectively, in MSQC, and 0.76%, 0.48%, and 0.41%, respectively, in ACS-NSQIP. Other studies show no significant difference in 30-day mortality between LC and RC with rates for both MIS options between 0.3% and 4.0%.^{1,2,4,8,16}

Other Studies Comparing RC and LC Colorectal Outcomes

Many studies comparing LC and RC MIS options show no significant difference in postoperative complication rates, though several show decreased hospital LOS and conversion rates for RC.^{1,2,4,6,18-20} Some studies show an advantage related to the intracorporeal anastomosis compared with the extracorporeal anastomosis for both RC and LC options.^{6,20-22} The learning curve for RC appears to be shorter than that for LC, and the adoption of RC is increasing, especially for rectal resections in the pelvis and for anastomotic suturing that accompanies colectomies.²¹⁻²⁵ Because of the ergonomic advantages, the RC approach is more appealing for many surgeons operating in the pelvis.^{1,2} Our study shows a higher proportion of rectal resections in the study population compared with the LC approach (48.4% vs 29.6%, $P < .0001$). Because 45–78% of

colorectal procedures are still done via the OC approach, there may be value to other MIS options if they result in a decrease in OC colorectal surgery and are associated with favorable outcomes.^{3,4,6–8} This regional and national database analysis suggests that RC outcomes are significantly favorable compared with OC.

MSQC and ACS-NSQIP databases do not contain cost data, and this metric was not evaluated in this study. Ultimately, cost comparisons will affect the value of MIS options for colorectal surgery. Earlier studies revealed higher RC institutional costs compared with LC costs.^{3,24–26} Because OC is most prevalent, a cost comparison to this approach is warranted as well. One such ACS-NSQIP study matching institutional data found that the median hospital costs of RC and OC surgery were not significantly different.³ Our group recently demonstrated in an analysis linking MSQC clinical metrics with adjudicated complete claims payments from the Michigan Value Collaborative that episode payments for RC were higher than those for the LC approach but lower than those for the OC approach.²⁷ Other studies that include the cost of healthcare resources are warranted to determine if the cost of RC purchase, maintenance, and supplies is mitigated by the favorable outcomes and potential health care resource advantages compared with OC, especially if significantly increasing the adoption of LC is not practical.²⁸

This study is limited by retrospective design. There is the possibility of selection bias and the possibility of unmeasured confounders, even with statistical adjustment. Data reliability depends on accurate data abstraction, but this may be a strength of the present study in that trained clinicians submit data for both risk-adjusted databases. Some patient characteristics may be significantly different because of the large numbers and may not be clinically different. For example, hypertension was a comorbidity in 7399 (48.2%) of OC cases, 18,065 (45.8%) of LC cases, and 1644 (46.6%) of RC cases ($P < .0001$), a result that is statistically different but may not be clinically different.

Although some of the significant differences in outcomes were the same in both MSQC and ACS-NSQIP databases, there were several differences between databases for individual complications. The number of patients in the ACS-NSQIP database is much larger, and this may have resulted in higher statistical power with respect to measuring individual complications with low rates. In addition, some of the covariates that could be controlled for were not available in both databases. *Finally, there is no way to elucidate surgeon decision-making, surgeon skill*

set, and surgeon experience for operative approaches and the impact this may have on the results of this study.

The evolution of risk-adjusted databases composed of data from surgeons of varying levels of expertise and hospitals of varying composition and demographics allowed the generation of data considered more generalizable than single-institution analyses and allowed metrics for quality improvement. Future investigations should consider risk-adjusted database limitations and which interventions may allow quality improvement in standardizing data reporting and abstraction for reliability. Application of the science of data analytics to promote standardized collection and analysis of high-quality data for the purposes of clinical research is worthy of further investigation.¹³

CONCLUSION

This outcomes comparison of 2 large multicenter-validated regional and national databases shows that minimally invasive LC and RC colorectal surgery are associated with significantly fewer postoperative adverse events and decreased hospital LOS compared with the OC approach. There are some outcomes inconsistencies between databases, and some results should be interpreted in context and with caution.

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